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Optimizing the control of foot-and-mouth disease in Denmark by simulation

Comparison of foot-and-mouth disease simulation models

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Technical University of Denmark

Optimizing the control of foot-and-mouth disease in Denmark by simulation

Comparison of foot-and-mouth disease simulation models

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Background

- Several models are used to simulate FMD.

- They vary in:
  - The way they work.
  - The way processes are modeled.
  - Ease of use.
  - Time and skills requirements to run the model.
  - Flexibility to include structural changes to the model.

Background

- Does that make a difference???

Background

- Which one to choose???

Background

- Would the choice result in a different consequence???

Objective

- Simulate the spread of FMD in Denmark using 3 popular FMD simulation models in order to:
    1. Compare the outcomes of the 3 models.
    2. Obtain insight into the differences between the models and examine their consequence on decision making.

Methods - models

- Davis Animal Disease Simulation (DADS) was developed to **DTU-DADS**.

- InterSpread Plus (**ISP**).

- North American Animal Disease Spread Model (**NAADSM**).

Methods – differences between models

- Major differences

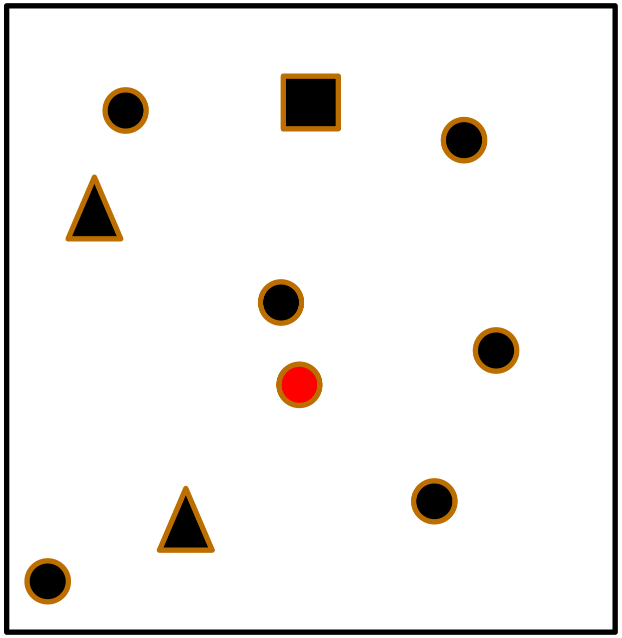
- Minor differences

Methods – major differences (1)

- Disease spread between herds in DTU-DADS and ISP through
  - Animal movements (direct contact).
  - Trucks moving animals to the abattoir.
  - Milk tanks.
  - Medium risk contact.
  - Low risk contact.
  - Local spread.
- In NAADSM through
  - Animal movements (direct contact).
  - Indirect contacts.
  - Local spread.

Methods – major differences (2)

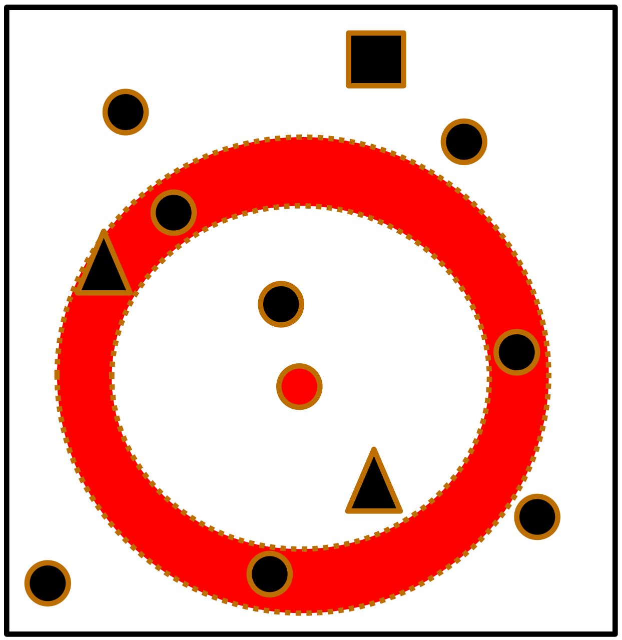
- Selection of new infections: in DTU-DADS



Probability = distance probability X
herd-type probability X
Probability disease transmission

Methods – major differences (2)

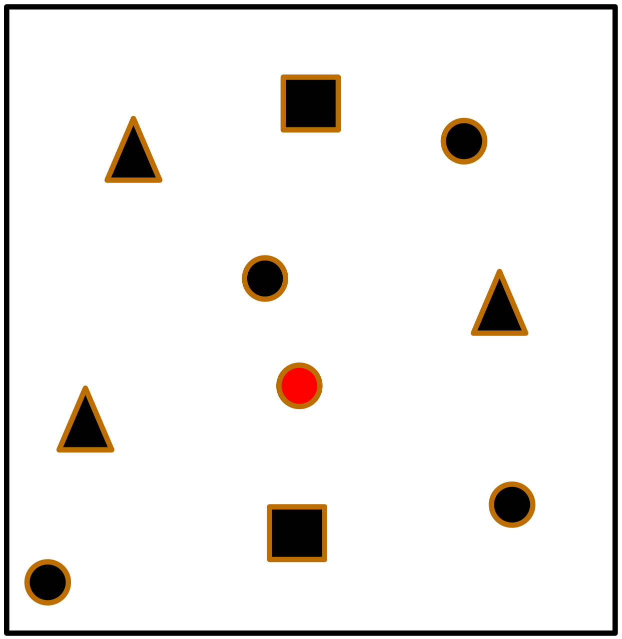
- Selection of new infections: in ISP



Probability = herd-type probability X
Probability disease transmission

Methods – major differences (2)

- Selection of new infections: in NAADSM contacts are herd-type dependent.



Probability = distance probability X Probability disease transmission

Methods – major differences (3)

- Index herds selected randomly for DTU-DADS and ISP:
  - Thousand cattle herds in high density cattle area.
  - Thousand cattle herds in low density cattle area.
  - Thousand swine herds in high density swine area.
  - Thousand swine herds in low density swine area.
  - Thousand sheep herds.
  - 1 iteration per index herd.
- Index herds in NAADSM:
  - Ten cattle herds in high density cattle area.
  - The model was run 100 iterations per index herd.

Methods – major differences (4)

- Initiation of vaccination and pre-emptive depopulation:
  - In DTU-DADS and ISP: based on the number of detected herds or days following first detection.
  - In NAADSM:
    - Vaccination: based on the number of detected herds.
    - Pre-emptive depopulation: based on days following first detection, <u>BUT always starts when first herd is detected</u>.

Methods – major differences (5)

- Disease progress within a herd:
  - In DTU-DADS, disease progress within a herd is modeled stochastically.
  - In ISP and NAADSM, disease progress is based on the average progress from the DTU-DADS.

Methods – minor differences (1)

- In overlapping zones:
  - A new surveillance visit will be made when 7 days have elapsed since the last visit.
  - This is possible in DTU-DADS, but not in ISP and NAADSM.

Methods – minor differences (2)

- Abattoir movements of pigs and sheep:
  - In ISP, a herd-specific lambda is used to model whether a movement would occur, and then the number of contacted herds is modeled.
  - In DTU-DADS the herd-specific lambda is used to model the number of herds an abattoir truck would contact on its way to the abattoir.

Methods – minor differences (3)

- All infected herds in DTU-DADS would eventually be detected.
- This is not the case in ISP and NAADSM.

Methods – minor differences (4)

- ISP over-estimates the number of surveillance visits in the vaccination zone.

Methods – minor differences (5)

- Tracing:
  - Tracing in DTU-DADS and NAADSM is restricted to 28 days (as recommended), while no restriction on tracing in ISP.
  - Only forward tracing is carried out in NAADSM.

Control scenarios

- Basic scenario: EU and Danish regulations and including 3 days national standstill.

- Pre-emptive depopulation in 500 meters:
  - 14 days following detection of first infected herd.
  - Following detection of 50 infected herds.

- Suppressive vaccination in 1,000 meters:
  - 14 days following detection of first infected herd.
  - Following detection of 50 infected herds.

Results– Basic Scenario

Median (5th and 95th) of the three models outcomes from epidemics started in cattle herds located in high density cattle area.

	DTU-DADS	ISP	NAADSM
Duration (days)	56[aa] (16-142)	80 (5-255)	120[a] (13-344)
Infected herds	67[aa] (13-245)	137 (3-696)	478[a] (5-6,169)
Depopulated herds	67[aa] (13-245)	141 (3-718)	301[a] (4-5,714)
Total costs* (× €10^6)	606[aa] (402-946)	703 (399-1,137)	1.290[a] (392-3,227)
Area (km^2)	9,869[aa] (567-28,687)	11,115 (0-35,178)	25,880[a] (5-52,392)

* Mean value

Results– Basic Scenario

Median (5^{th} and 95^{th}) of outcomes of two models from epidemics started in cattle herds located in low density cattle area.

	DTU-DADS	ISP
Duration (days)	71 (19-179)	65 (2-226)
Infected herds	94 (15-371)	80 (2-521)
Depopulated herds	94 (15-371)	79 (1-539)
Total costs* ($\times$ €10^6)	**652[a] (416-1,061)**	**613 (363-1,001)**
Area (km^2)	**11,414[a] (339-36,207)**	**5,994 (0-32,588)**

* Mean value

Results– Basic Scenario

Median (5th and 95th) of outcomes of two models from epidemics started in swine herds located in high density swine area.

	DTU-DADS	ISP
Duration (days)	43[a] (8-130)	25 (2-180)
Infected herds	36[a] (5-195)	12 (1-313)
Depopulated herds	36[a] (5-195)	12 (1-322)
Total costs* ($\times$ €10^6)	548[a] (376-869)	508 (341-961)
Area (km^2)	5,053[a] (11-27,254)	771 (0-22,680)

* Mean value

Results– Basic Scenario

Median (5th and 95th) of outcomes of two models from epidemics started in sheep herds.

	DTU-DADS	ISP
Duration (days)	38[a] (6-139)	9 (2-155)
Infected herds	29[a] (3-198)	4 (1-222)
Depopulated herds	29 (3-198)	4 (1-233)
Total costs* ($\times$€10^6)	531[a] (364-876)	458 (345-723)
Area (km^2)	3,881[a] (0-24,473)	1 (0-17,538)

* Mean value

Results– Pre-emptive depopulation

Median (5th and 95th) of outcomes of two models from epidemics started in cattle herds located in high density cattle area.

	Depopulation 14 days		Depopulation 50 herds	
	DTU-DADS	ISP	DTU-DADS	ISP
Duration (days)	**46[a] (16-100)**	**66 (5-184)**	49[a] (16-105)	69 (5-190)
Infected herds	**59[a] (12-177)**	**109 (3-469)**	63[a] (13-179)	120 (3-470)
Depopulated herds	84[a] (13-282)	175 (3-806)	76[a] (13-303)	175 (3-828)
Total costs* ($\times$€10^6)	**558[a] (403-773)**	**634 (398-948)**	564[a] (402-786)	643 (399-952)
Area (km^2)	9,372[a] (527-25,448)	9,779 (0-31,422)	9,295 (566-24,846)	10,100 (0-32,624)

* Mean value

Results– Suppressive vaccination

Median (5th and 95th) of outcomes of the three models from epidemics started in cattle herds located in high density cattle area using suppressive vaccination 14 days following first detection.

	DTU-DADS	ISP	NAADSM
Duration (days)	**47[aa] (16-100)**	**59 (3-141)**	**99[a] (22-344)**
Infected herds	**60[aa] (12-193)**	93 (3-368)	**398[a] (9-4,017)**
Depopulated herds	60[aa] (12-193)	96 (3-383)	376[a] (8-3,767)
Vaccinated herds	**90[aa] (3-350)**	160 (0-711)	**657[a] (0-5,197)**
Total costs* (€ × 10^6)	**558[aa] (400-788)**	**588 (400-803)**	**1,132[a] (416-2,850)**
Area (km^2)	10,473[ca] (549-25,236)	8,218 (0-28,349)	27,846[a] (26-50,398)

* Mean value

Results– Suppressive vaccination

Median (5th and 95th) of outcomes of the three models from epidemics started in cattle herds located in high density cattle area using suppressive vaccination following detection 50 herds.

	DTU-DADS	ISP	NAADSM
Duration (days)	**50[aa] (16-105)**	**62 (5-155)**	**102[a] (17-344)**
Infected herds	64[aa] (13-181)	110 (3-377)	395[a] (8-3,230)
Depopulated herds	64[aa] (13-181)	114 (3-393)	372[a] (7-2,918)
Vaccinated herds	44[aa] (0-386)	144 (0-830)	622[a] (0-4,412)
Total costs* (€ × 10^6)	**569[aa] (402-788)**	**605 (401-858)**	**1,083[a] (405-2,574)**
Area (km^2)	10,687[ca] (566-25,337)	9,440 (0-28,552)	27,211[a] (18-51,620)

* Mean value

Results– Total Costs

Mean (5th and 95th) of the total costs from epidemics started in cattle herds located in high density cattle area.

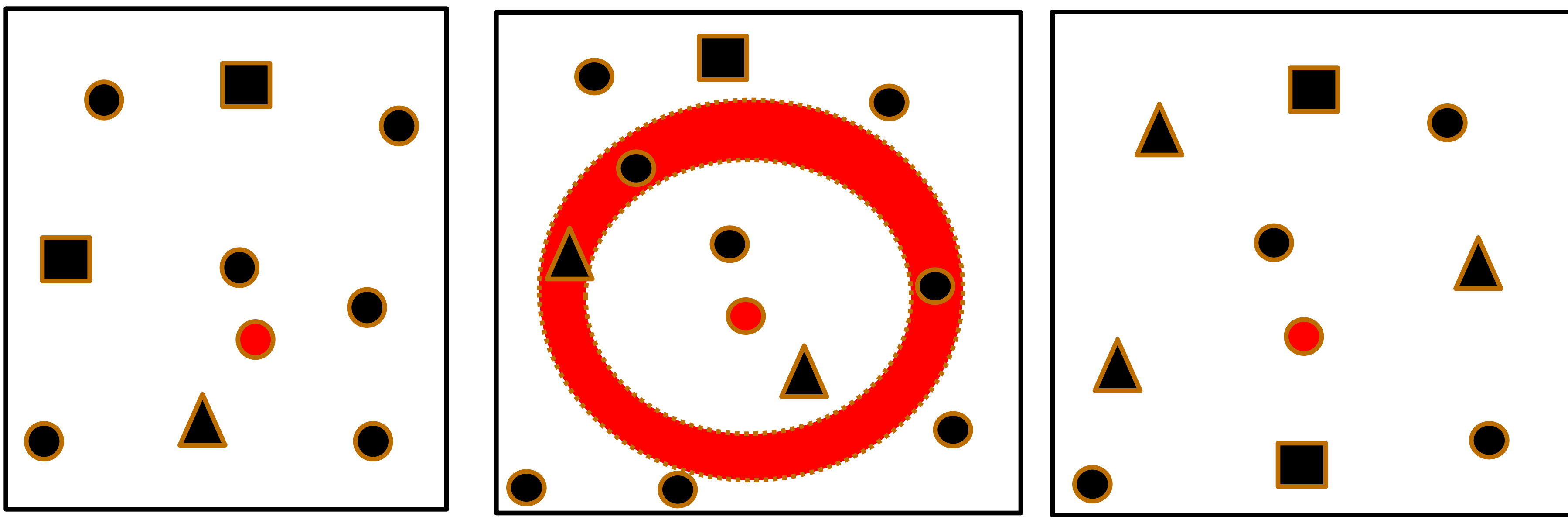
Scenario	DTU-DADS	ISP	NAADSM
Basic	606 (402-946)	703 (399-1,137)	1.290 (392-3,227)
Depopulation 14 days	**558 (403-773)**	634 (398-948)	
Depopulation 50 herds	564 (402-786)	643 (399-952)	
Vaccinated 14 days	**558 (400-788)**	**588 (400-803)**	1,131 (414-2,866)
Vaccinated 50 herds	569 (402-788)	605 (401-858)	**1,083 (400-2,575)**

Discussion (1)

- NAADSM predicted the largest, longest duration and costliest epidemics.
- DTU-DADS predicted larger, longer duration and costlier epidemics than ISP, except when epidemics started in cattle herds located in high density cattle area.
- NAADSM showed the high variability, while DTU-DADS showed the lowest.

Discussion (2)

- Selection of new infections



DTU-DADS ISP NAADSM

Conclusions (1)

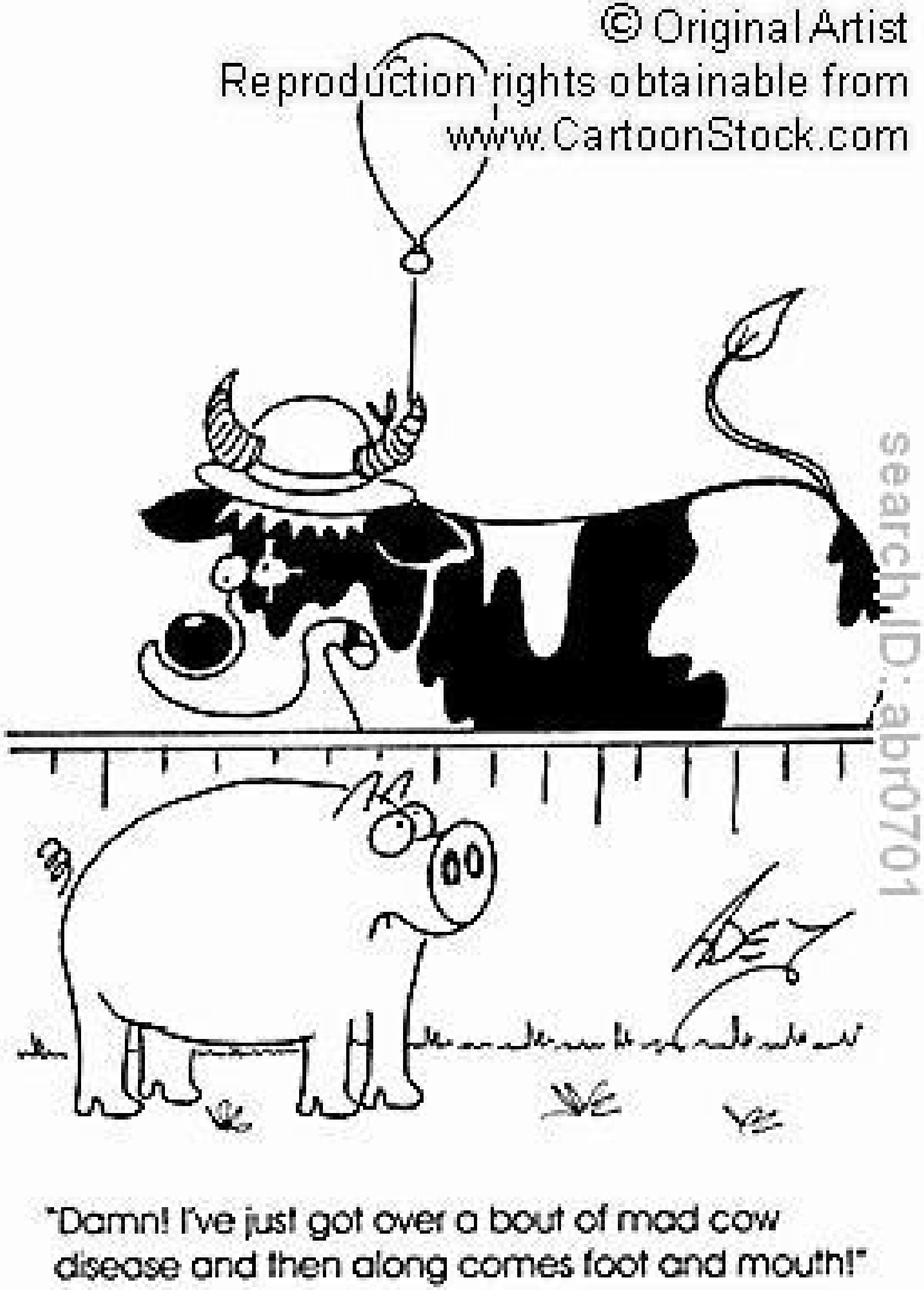
- The models predicted different epidemic duration, size, costs and number of infected herds.
- The decision of control might change based on the chosen model, but given the large uncertainty, the effect is small.

Conclusions (2)

- Using more than one model has the advantages of:
  - Better insight into disease spread mechanisms.
  - Better understanding of modeling processes.
  - Limit typing and coding errors.

Conclusions (3)

- DTU-DADS and ISP are detailed enough to run on detailed data such as the Danish.
- NAADSM needs further development to be more flexible in running alternative scenarios.



Thank You for attention